



## Department of Energy

Washington, DC 20585

**Safety Evaluation Report  
NuPac PAS-1 Packaging with Payload B  
Rev. 0, Certificate of Compliance USA/9184/B(U) (DOE)  
Docket 94-22-9184**

### Introduction

This Safety Evaluation Report (SER) documents the review of the NuPac PAS-1 Consolidated Safety Analysis Report for Packaging (SARP), Revision 5.

### Chapter 1, General Information

The PAS-1 package has been used to ship coolant samples from fission reactors (Payload A). The proposed application addressed in this Safety Evaluation Report is to use the PAS-1 packaging to ship fissile-exempt quantity samples of liquid and solid contents from the Hanford fission product waste tanks. These packages, with the contents identified as Payload B, will be shipped as exclusive use. This SER summarizes the evaluation of the PAS-1 package design for this application.

#### **1.1 Areas of Review**

**Payload A Contents:** The PAS-1 SARP, Chapter 1, was reviewed and approved by the Nuclear Regulatory Commission (NRC) for adequacy of the description of the PAS-1 packaging with Payload A contents.

**Payload B Contents:** The approved description of the PAS-1 packaging was augmented for use in shipping Payload B contents for the Department of Energy (DOE). Payload B produces substantial quantities of hydrogen gas due to radiolysis and "thermolysis." ("Thermolysis" is the production of hydrogen by temperature-dependent, chemical decomposition of the contents of the Hanford waste tanks.) The PAS-1 SARP portion of Chapter 1 that addresses the description of a PAS-1 package with Payload B contents was reviewed by the EM-70 Packaging Certification Team for the adequacy of the description of the packaging with Payload B. The package description, operating features, and package behavior during normal transport conditions were included in the review. The current review of the SARP for the PAS-1 packaging covers only the portion of the SARP revised for the Payload B contents. The portion of the SARP approved for Payload A contents that remained unchanged for Payload B contents was not re-reviewed.

## 1.2 Acceptance Criteria

An applicant requesting a Certificate of Compliance for a packaging for (1) the shipment of fissile material and (2) for a Type B quantity of radioactive material, must provide a SARP for the packaging with contents. The SARP documents evidence that the package complies with the appropriate sections of 10 CFR Part 71, 49 CFR Part 173, and U.S. Department of Energy Order 460.1A.

The SARP for the PAS-1 packaging with Payload A contents was reviewed and approved by the NRC for compliance with 10 CFR Part 71. The result of the review was the issuance of NRC Certificate of Compliance Revision 3, USA/9184/B(U) on April 17, 1989.

## 1.3 Review Procedure

Only the portion of Chapter 1 that was changed for the Payload B contents was reviewed.

### 1.3.1 Packaging Description

The Payload B contents consist of samples of the liquid and solid contents of waste tanks in fissile-material-exempt quantities. A package is fissile material exempt if the total fissile material content is less than 15 grams. The total fissile material content in Payload B is less than 9 grams.

The PAS-1 packaging with Payload B is a Type B, Category II package.

Payload B consists of up to 8 liquid sample carriers each with a capacity of one 500 ml or two 250 ml sample containers. The maximum total sample capacity is 4 liters. The sample containers are bottles or jars which are not claimed toward packaging containment. The SARP is silent about the existence of vents in the sample containers. The stainless steel or lead-filled vented sample carriers are positioned in and supported by a sample rack that provides a minimum of 16 liters of vermiculite to absorb any liquid leakage. The vermiculite, which can absorb over 50% of its volume of water, is confined by expanded metal screens. The arrangement for Payload B is shown in Appendix 1.3.1 of the SARP.

For radioactive content and gas generation control, Payload B is restricted by decay heat generation rates, total organic carbon content (TOC), and aluminum content. The maximum limits on the decay heat, percent TOC, percent aluminum, and maximum shipping volume in a package for various categories of Payload B are shown in Table 1.1, below. When the maximum shipping volume is limited to two liters, the containers must be shipped in a maximum of four sample carriers. The maximum decay heat generation rate for Payload B in the PAS-1 package is 0.0968 watts.

**Table 1**  
**Upper Bound Limits for Categories of Payload B**  
**(From Table 1.2.3-1 of the PAS-1 SARP)**

Category	Decay Heat (watts/liter)	TOC (percent)	Aluminum (percent)	Maximum Shipping Volume (liters)
1	0.0242	4.7	12.0	2
2	0.0242	0.3	7.0	4
3	0.0055	3.7	20.0	2
4	0.0055	1.8	12.0	4
5	0.00013	10.0	8.2	2
6	0.00013	4.0	7.0	4

The PAS-1 packaging components that control the package response to Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) are described in the SARP. These components, which primarily include the steel shell and foam overpack, the lead shielding, and the containment vessels, are described in sufficient detail in Section 1.3.1 of the PAS-1 SARP to provide a basis for the evaluation of the PAS-1 package with Payload B contents.

The existing packaging has been designed to and certified by the NRC to meet the requirements of 10 CFR Part 71 for Payload A but, because it predates the NRC recommendation that packaging be designed to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, it is not designed and fabricated to the Code. Payload B has a maximum normal operating pressure (MNOP) of 33 psig which is considerably higher than the 8.4 psig MNOP of Payload A. Even though the containment boundary is not designed to the ASME B&PV Code, the maximum stress across the primary containment vessel (PCV) for Payload B was compared to an ASME allowable stress based on Section III, Subsection ND-3321 of the B&PV for ASME SA-240 Type 304 stainless steel at 200°F.

Only two PAS-1 packages, serial numbers 2162-026 and 2162-027, have been built for Payload B service. Because the PAS-1 package is not designed to the ASME B&PV Code, the Certificate of Compliance for Payload B is limited to package serial numbers 2162-026 and 2162-027. If it is desired to build additional packages, application should be made to the Headquarters Certifying Official before programmatic funds are committed.

### **1.3.2 Operational Features of Package**

The operational features of the PAS-1 package with Payload B contents are shown in Appendix 1.3.1 of the SARP. There are no complex operational

requirements connected with the packaging that have any transport significance. There are, however, important operational procedures required to ensure that the Payload B contents will not generate hydrogen in excess of an MNOP of 33 psig. These procedures include the determination of the TOC and the aluminum content of a Payload B.

In addition to allowing the determination of the MNOP, these operational procedures are necessary to estimate the maximum allowable shipment time following closure of the PCV to keep the hydrogen concentration in the PCV to less than 4 molar percent. These and other operating procedures are given in Chapter 7 of the SARP.

The acceptance tests and maintenance program are described in Chapter 8 of the SARP.

### **1.3.3 Summary of Package Evaluation**

The package evaluation consists of comparing the PAS-1 packaging with Payload B to the requirements of 10 CFR Part 71. Included are the general standards for the package, the behavior of the package under NCT and the response of the package to HAC.

#### **1.3.3.1 General Standards**

The PAS-1 packaging with Payload B contents differs from the PAS-1 packaging with Payload A certified by the NRC only by the contents. The difference between the effects on the general standards for all packages, as well as the NCT for Payload B from that of the Payload A already certified by the NRC, is due to the hydrogen production of Payload B. In addition, while both payloads may be liquid, only Payload B contains plutonium.

The total plutonium in the liquid contents of Payload B must be less than 20 Ci. Based on the highest predicted concentration of plutonium from any one of all of the Hanford waste tanks, the maximum plutonium activity in a PAS-1 package with Payload B is 0.25 Ci.

A package is fissile-material-exempt if the total fissile material content is less than 15 grams. The total fissile material content in Payload B is less than 9 grams.

A heat balance on the package surface in ambient air at 100°F in the shade with Payload B contents results in a surface temperature of less than the upper limit of 180°F allowed for an exclusive use shipment.

#### **1.3.3.2 Normal Conditions of Transport**

The primary issues for the PAS-1 package with Payload B contents are associated with the hydrogen generation following the closure of the PCV. The hydrogen generated will build up beyond the lower flammability limit (4 molar percent) resulting in the combination of an increasing chemically reactive

mixture of gases with the radioactive contents in the PCV. The time elapsed between the closure of the PCV and the buildup of hydrogen to 4 molar percent in the PCV will dictate the maximum time allowed for shipment.

A second issue is the pressure buildup in the PCV due to one year of hydrogen generation following closure. This pressure is the MNOP upon which the stress analysis of the containment vessel is based. The maximum hydrogen production rate in the PAS-1 package occurs for Payload B, category 5. Hydrogen produced by Payload B will reach a concentration of about 4 molar percent in the PCV in about 90 days based on a sample temperature of 120°F. Using the steady-state sample temperature of 126°F, the hydrogen concentration in the PCV will reach 4 molar percent in 51 days for the limiting payload for hydrogen production.

For the PAS-1 package with Payload B, category 5 contents, the MNOP one year after closure is given in the SARP as 33 psig at the steady-state temperature of 126°F due to hydrogen build-up. The maximum pressure across the containment vessel with a reduced external pressure of 3.5 psia at one year is 44.2 psig. This pressure difference results in a maximum stress in the PCV of less than 23,000 psi which is less than the maximum allowable stress for ASME SA-240 Type 304 stainless steel given in ASME B&PV Code Section III, Subsection NB-3321. The stresses in the lid bolts due to the pressure difference of 44.2 psig across the lid of the PCV are less than the yield strength of the bolt material.

#### 1.3.3.3 Hypothetical Accident Conditions

The mass of the PAS-1 packaging with the Payload B is virtually the same as that of Payload A. Thus, the structural portion of the HAC for the PAS-1 packaging with Payload B is the same as for the already certified packaging with Payload A. The components important to safety (lead shielding and O-ring containment seal) of the PAS-1 packaging with Payload B in the thermal portion of the HAC do not reach their allowable temperature limits. The containment stress will be bounded by the NCT because, while the internal pressure in the PCV will be slightly greater for HAC than NCT, the reduced external pressure is applicable only to the NCT resulting in a larger pressure differential across the PCV for NCT than for HAC.

#### 1.3.4 Quality Control and Assurance Requirements

A quality assurance program has been described in the SARP for the PAS-1 package with Payload A contents. This program has been augmented for the Payload B contents.

### 1.4 Findings and Conclusions

The review of Chapter 1, General Information, verifies the SARP contains all the information necessary to demonstrate that the PAS-1 package with Payload B conforms to 10 CFR Part 71. Two constraints are necessary on the PAS-1 package for Payload B service as follows:

1. Service with Payload B is limited to PAS-1 packages serial numbers 2162-026 and 2162-027.
2. The generation of hydrogen in the PCV discussed in Chapter 3 of the SARP places constraints on the shipment of the packages. These constraints are based on maintaining a lower flammability hydrogen concentration limit in the PCV. The hydrogen concentration constraint of a maximum of 4 molar percent in the PCV limits the maximum elapsed time from the closure of the PCV to delivery of the shipment. This elapsed time must be less than 25 days.

## **Chapter 2, Structural Evaluation**

### **2.1 Areas of Review**

The review of the structural design of the PAS-1 SARP, Chapter 2 Revision 5, includes only those features of the PAS-1 package that are subjected to increased environmental and/or stress conditions as a result of adding Payload B to the contents. This package has been previously approved by the NRC, and a re-review of the previously approved sections (denoted Revision 0 and dated March 31, 1989) has not been attempted. Only the changes specific to Payload B are considered in this SER and the only change affecting the structural evaluation specific to Payload B is the increased internal pressure.

### **2.2 Acceptance Criteria**

Package structural design is acceptable if it can be shown that:

1. The package was designed using methods and criteria appropriate for the behavior and function of the design consistent with prevailing industrial codes, standards, and practices for structures and materials.
2. There are no structural or material effects that unacceptably degrade containment and shielding functions of the packaging under NCT and HAC.

### **2.3 Review Procedure**

To satisfy the regulatory safety requirements the PAS-1 Package with Payload B must contain the contents and provide shielding from the radiation of the contents. Structural evaluations of the PAS-1 Package are based on the ability to meet these goals in both the NCT and HAC environments. The evaluations for NCT were accomplished via analyses.

The effects of internal pressure are discussed in the PAS-1 SARP in Section 2.6 where the MNOP for one year after closure of the containment vessel is stated as 33 psig. The maximum pressure difference across the PCV with the reduced external pressure of 3.5 psia specified for NCT is stated as 44.2 psi.

The maximum stress resulting from this pressure in the PCV is determined to be 22,987 psi. This stress is shown to be less than yield in the SARP.

Confirmatory calculations by the EM-70 Staff show the wall stress in the PCV is greater under NCT than HAC. The pressure difference across the PCV wall increases from 33.0 psi to 33.9 psi at the HAC waste sample temperature and increases the stress in the PCV wall at HAC from 17,162 psi to 17,630 psi. However, the stress in the PCV wall under NCT is higher, 22,987 psi, because, by definition, the wall stress is evaluated with a reduced external pressure of 3.5 psia which raises the pressure difference across the PCV to 44.2 psi compared to the 33.9 psi at HAC. Thus, the maximum wall stress occurs under NCT rather than HAC.

EM-70 Staff has verified the maximum stress in the PCV is 22,987 psi; however the Staff does not agree with the SARP in comparing the maximum stress with the yield stress of the PCV. The Staff rather compares the maximum stress to the appropriate ASME design specification. Because the PAS-1 with Payload B is a Category II packaging (see Section 1.3 of this SER), the appropriate ASME design specification to be considered for the containment is ASME Section III, Div. 1, ND. The EM-70 Staff has determined that the maximum stress (22,987 psi) is less than the ASME Section III, Div. 1, ND allowable stress of 27,450 psi.

The lid bolts are shown in the SARP to meet the requirement (listed in the SARP and previously approved by the NRC) of yield stress for the bolt material.

The PAS-1 package has been designed to and certified by the NRC to meet the requirements of 10 CFR Part 71 for Payload A but, because it predates the NRC recommendation that packaging be designed to the ASME B&PV Code, it is not designed and fabricated to the Code. Only two PAS-1 packages, serial numbers 2162-026 and 2162-027, have been built for Payload B service. Because the PAS-1 package is not designed to the ASME B&PV Code, the Certificate of Compliance for Payload B is limited to package serial numbers 2162-026 and 2162-027. If it is desired to build additional packages, application should be made to the Headquarters Certifying Official before any money is committed.

## **2.4 Findings and Conclusions**

Based on the structural test and analysis results presented in the PAS-1 SARP and confirmatory calculations, and based on the previous certification approval provided by the NRC first in 1984 and renewed in 1986 and 1989, the EM-70 Staff concludes that the structural design of the package with Payload B is in compliance with 10 CFR Part 71 requirements. Nevertheless, because the PAS-1 package is not built to the ASME B&PV Code as recommended by the NRC, only packages with serial numbers 2162-026 and 2162-027 shall be authorized for service with Payload B.

### **Chapter 3, Thermal Evaluation**

#### **3.1 Areas of Review**

The review of the thermal design of the PAS-1 SARP, Chapter 3 Revision 5, includes only those features of the PAS-1 package that are subjected to increased environmental and/or stress conditions by Payload B. This package has been previously approved by the NRC, and a re-review of the previously approved sections (denoted Revision 0 and dated March 31, 1989) has not been attempted. Only the changes specific to Payload B are considered in this SER. The portion of Chapter 3 of the PAS-1 SARP that addresses the thermal evaluation of a PAS-1 package with Payload B contents was reviewed for the adequacy of the evaluation of the thermal response of the packaging to the heat generation of Payload B and to the gas production by radiolysis and thermolysis of Payload B subject to NCT and HAC.

#### **3.2 Acceptance Criteria**

Package thermal design is acceptable for Payload B if it can be shown that:

1. No accessible surface temperature of the package in 100°F still air without insolation exceeds the 180°F limit for an exclusive use shipment.
2. There are no structural or material effects that unacceptably degrade containment and shielding functions of the packaging under NCT and HAC.

#### **3.3 Review Procedure**

The PAS-1 packaging components that control the package response to the NCT and HAC thermal environments are the steel shell of the overpack, the foam of the overpack, the lead shielding, the containment vessels, the containment vessel seals, and the Payload B contents.

To review the PAS-1 Package with Payload B, the EM-70 Staff verified the thermal properties of Payload B and the package components as specified in the SARP and performed confirmatory calculations of the package behavior in both NCT and HAC environments.

The SARP presents the results of thermal evaluations for most NCT and all HAC using the finite difference computer code HEATING7.2b developed by Oak Ridge National Laboratory for shipping cask evaluations. Two-dimensional axisymmetric models were used to simulate the package geometry. Two sample carrier models were considered: the lead-shielded, tall sample carrier, and the stainless steel, short sample carriers.

##### **3.3.1 Normal Conditions of Transport**

The PAS-1 Payload B packaging surface temperature is within the regulatory safety limit for exclusive use. The maximum heat load for the Payload B

contents is 0.0968 watts as specified in Table 1.2.3-1 of the SARP for Category 2 contents. The SARP uses the assumption that, because of the low content decay heat loading, the surface temperature of the package in the shade (without insolation) is the same as the temperature of the air. The EM-70 Staff concurs with this assumption and agrees that the PAS-1 Package with Payload B satisfies the regulatory safety requirement that the accessible surface temperature in the shade be no more than 180°F for exclusive use shipment.

The steady state temperature of the PCV and contents for the NCT environment is important to determining the MNOP because gas generation by thermolysis increases strongly with temperature. The SARP presents thermal evaluations for the NCT thermal conditions with periodic insolation applied to the surfaces of the package [based on the values given in 10 CFR 71.71(c)] with the absorptivity of 0.3 and the emissivity of 0.8 in 100°F still air with content decay heat conservatively assumed to be 0.48 watts (vis-à-vis 0.0968 watts specified in Table 1.2.3-1). The applicant analyzed the package configurations associated with each sample carrier model. The thermal models for the stainless steel and for the lead-shielded sample carriers are shown in Figures 3.6.7-1 and 3.6.7-3 respectively in the PAS-1 SARP. The upper bound temperatures occurred in the package utilizing the stainless steel sample carriers. The SARP analysis predicts a sample temperature of 119.48°F after 22 days, estimates a sample temperature of 121°F after 60 days, and predicts a steady-state sample temperature under NCT of 126°F. The maximum foam temperature (at the top of the package) was calculated to be 140°F.

Confirmatory calculations by the EM-70 Staff of the package surface temperatures and the steady-state sample temperatures verify that the results presented in the SARP are reasonable and conservative.

The EM-70 Staff agrees with the SARP that the functions of the packaging are not compromised by their operating temperature for the NCT environment. The temperature of all packaging components will be less than the maximum foam temperature, 140°F, during NCT.

In the SARP the MNOP in the PCV is caused by the production of hydrogen and other gases in the Payload B sample contents due to radiolysis and thermolysis in the NCT environment. Other sources of the pressure increase in the PCV are due to the increase of the temperature of the cavity gas initially at atmospheric pressure and 70°F temperature as well as the increase of the saturated steam pressure caused by the increase in the sample content temperature following the loading into the PAS-1 packaging. The EM-70 Staff agrees with the SARP model.

In the SARP the hydrogen generation rate by radiolysis is determined by using a classical energy absorption model that assumes that  $G(H_2)$  molecules of hydrogen are produced per 100 eV of radioactive decay energy. The G-value for Payload B is assumed to be 0.6. The EM-70 Staff agrees with the SARP radiolysis model and the G-value used.

In the SARP the hydrogen generation rate by thermolysis is based on an empirical model that utilizes the amount of aluminum and total organic carbon in the payload samples with the temperature dependency determined by the Arrhenius rate model with activation energy of 135 kJ/mole. The generation rate of other flammable gases (ammonia and methane) is assumed to scale with the total hydrogen generation rate. The total gas generation rate is assumed to be 4x the total hydrogen generation rate. The empirical models used in the SARP to calculate the hydrogen generation rates of the various Payload B categories and the results given in Table 3.7.4.8-2 were reviewed by the EM-70 Staff and found to be acceptable.

Table 3.7.4.8-2 of the SARP shows that the MNOP (which by definition is evaluated at NCT) in the PCV would reach 47.7 psia (33 psig) for Payload B, category 5 which is the limiting payload. Confirmatory calculations by the EM-70 Staff of the MNOP verify that the pressure results are reasonable and conservative. As shown in Chapter 2 of this SER, this pressure does not produce stresses in the PCV that exceed the allowable stress limits. The EM-70 Staff also notes that the thermal stresses in the containment vessels are small due to the low temperature gradients in the vessel walls.

The flammability limit of hydrogen gas in air is 5 molar percent. However, the flammability limit of hydrogen gas in the PCV of PAS-1 used in the SARP is 4 molar percent due to the additional oxidizers from the decomposition of the Payload B. The EM-70 Staff agrees with lowering the flammability limit to 4% to account for additional oxidizers.

Table 3.7.4.8-2 of the SARP shows that the hydrogen concentration in the PCV would reach 4 molar percent in about 90 days based on the estimated sample temperature of 120°F which is reached in 60 days. The EM-70 Staff disagrees with basing the hydrogen concentration on any sample temperature less than the steady-state temperature of 126°F. The Staff calculates that the hydrogen concentration will reach 4 molar percent in the PCV in 51 days for Payload B, category 5 which is the limiting payload. To allow a safety margin of two, the shipping time shall not exceed 25 days.

### **3.3.2 Hypothetical Accident Conditions**

The thermal portion of the HAC environment [10 CFR 71.73(c)(3)] was mathematically simulated using HEATING7.2b. The drop and puncture tests of the HAC resulted in crushing the foam which reduced the outer diameter and height of the package by reducing the thickness (and hence increasing the density) of the foam. The thermal conductivity of the crushed foam is larger than that of the undamaged foam. The initial condition of the package was the steady-state temperature distribution without insolation. The heat flux on the surface of the package from the regulatory radiation source and natural convection of air at 1475°F was applied for 30 minutes. The package was allowed to cool by radiation and natural convection to the environment and air at 100°F. The maximum temperatures of the components important to safety occurred in the package following the fire. The maximum temperatures of these

components, as calculated by the applicant, as well as their design temperature limits are shown in Table 2, below.

**Table 2**  
**Calculated Maximum Temperatures in HAC**  
**Environment and Design Temperature Limits for**  
**Each Component**

Component	Temperature, °F	
	Maximum	Allowable
Overpack	1473	2750
Cask Outer Surface	295	2750
Lead	270	621
Seal	132	400
Waste Sample	137	N/A

Confirmatory calculations by the EM-70 Staff of the thermal response of the damaged package to the 1475°F, 30 minute thermal incident verify that the above results are reasonable and conservative.

The EM-70 Staff agrees with the SARP that the hydrogen generated is also bounded by NCT rather than HAC even though the maximum temperature that the waste samples experience during an HAC is greater than the maximum steady-state temperature for NCT. The hydrogen generated and the containment pressures are bounded by those of the NCT because the length of time the HAC temperature exceeds the steady-state temperature is short (on the order of several days). Other than the charring of the foam, the component temperatures do not approach their allowable temperatures during the HAC. Thus, the functions of the PAS-1 packaging (containment and shielding) are not affected by the HAC environment.

### **3.4 Findings and Conclusions**

The thermal analysis presented in the SARP, as confirmed by the EM-70 Staff, demonstrates that the PAS-1 Payload B packaging design meets the surface temperature requirements of 10 CFR 71.43(g) and the requirements of 10 CFR 71.51 for NCT and HAC environments provided the shipping time is limited to no more than 25 days.

## **Chapter 4, Containment**

### **4.1 Areas of Review**

The review of the containment design of the PAS-1 SARP, Chapter 4 Revision 5, includes only those features of the PAS-1 package that are subjected to

increased environmental and/or stress conditions as a result of the addition of Payload B considered in the revised SARP. This package has been previously approved by the NRC, and a re-review of the previously approved sections (denoted Revision 0 and dated March 31, 1989) has not been attempted. The portion of Chapter 4 of the PAS-1 SARP that addresses the containment evaluation of a PAS-1 package with Payload B contents was reviewed for the adequacy of the evaluation of the containment response of the package subject to NCT and HAC.

#### **4.2 Acceptance Criteria**

Package containment design is acceptable for Payload B if it can be shown that there are no structural or material effects introduced by Payload B that unacceptably degrade containment function of the packaging subject to NCT and HAC.

#### **4.3 Review Procedures**

For Payload A, the NRC accepted that the PAS-1 provides leak-tight ( $<1 \times 10^{-7}$  cc/s air) containment for both NCT and HAC environments which according to ANSI-N14.5 corresponds to a radioactivity leakage rate of zero. The SARP claims that Payload B does not challenge the containment capability of the PAS-1 package.

The EM-70 Staff determined upon review of Payload B that it does not offer any new challenges to the containment capability of the PAS-1 package for both NCT and HAC environments.

#### **4.4 Evaluation Findings and Conclusions**

The containment analysis and proposed leak testing procedures presented in the SARP and confirmed by the EM-70 Staff demonstrate that the package design with Payload B meets the applicable requirements for containment in 10 CFR Part 71.

### **Chapter 5. Shielding Evaluation**

#### **5.1 Areas of Review**

Chapter 5 of the PAS-1 SARP was reviewed for adequacy of the shielding design and analysis of the PAS-1 Packaging for Payload B. Payload A was previously addressed by the NRC.

#### **5.2 Acceptance Criteria**

Payload B radiation levels external to the package will be acceptable if they are less than those of Payload A.

### 5.3 Review Procedures

#### 5.3.1 Shielding design features and design criteria

The primary shielding design feature (for gamma radiation) of the PAS-1 packaging is a lead shield between the inner and outer walls of the SCV. The thickness of the lead at the sides and bottom of the packaging is 5.1 inches (12.954 cm); the lid of the PAS-1 contains 4.8 inches (12.192 cm) of lead. Additional shielding is provided by the steel plates of both the PCV and SCV. No special shielding is provided for neutrons, which are an insignificant source term for the PAS-1 contents.

The PAS-1 packaging was originally designed and analyzed for exclusive-use shipment of Payload A. Compliance with the applicable acceptance criteria defined in Section 5.2 above was previously demonstrated in the SARP, and the PAS-1 was certified for Payload A by the NRC. Consequently, the analysis approach for Payload B was to demonstrate that the radiation levels external to the PAS-1 with Payload B are less than those with Payload A. As discussed below, the radiation levels at the side of the package were compared.

#### 5.3.2 Source specification

Section 1.2.3.2 of the SARP specifies the allowed contents for Payload B. Additional detail is provided in Section 5.2. The radionuclide inventory used for developing the gamma source term was derived from the highest predicted concentration of 64 nuclides in any of the Hanford tanks. The total activity of these nuclides is approximately 835 Ci, and the heat load is approximately 2.7 W. The actual content of the packaging is limited to 0.0968 W. Section 7.6 of the SARP provides for verification that Payload B satisfies this heat limit prior to shipment.

Based on the radionuclide inventory of Payload B, the gamma source strength and energies reported in the SARP were computed using the computer code MicroShield.

The primary radionuclides (based on activity and heat load) of Payload B are  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$ , and their daughters. The significant contributions to the decay-gamma source term are from the decay of  $^{137\text{m}}\text{Ba}$  and  $^{60}\text{Co}$ . Table 5-2 and page 5-9 of the SARP identify a source term of 12.0 Ci for  $^{137\text{m}}\text{Ba}$  and  $3 \times 10^{-3}$  Ci for  $^{60}\text{Co}$ . Even though the latter is only a small fraction of the total activity, it contributes the majority of the decay-gamma dose, as shown in the table on page 5-10 of the SARP.

The EM-70 Staff reviewed the decay-gamma source specification for Payload B provided in the SARP and agrees that, with the verification procedures provided in Chapter 7, it is reasonable and conservative.

In addition to the gammas produced directly from nuclide decay, the beta decay of  $^{90}\text{Y}$  will produce bremsstrahlung radiation. The significance of this radiation is discussed in Section 5.3.4 below.

Based on the radionuclide inventory of Payload B, the SARP ignored a neutron source term. The EM-70 Staff concurs that the neutron source term for Payload B would be insignificant.

### 5.3.3 Model specification

The model for the shielding analysis of Payload B under NCT was described in Section 5.2 and Appendix 5.3 of the SARP. To conservatively evaluate shielding, the sample carrier was ignored, and a point source (which neglects self-shielding) was assumed. A simplified model for the dose rate at the side of the PAS-1 considered only the 0.75-in. (1.905-cm) thickness of the steel PCV, the 0.38-in. (0.9652-cm) thickness of the inner and outer wall of the SCV, and the 5.1-in. (12.954-cm) thickness of lead shielding. Other packaging materials (e.g., overpack) and their thickness were ignored, so that the distance between the dose point on the side of the PAS-1 and the source was also conservatively reduced.

As noted in Section 5.3.1 above, the acceptability of the radiation levels from Payload B was based on a comparison of the dose rate at the side of the PAS-1 for Payload B with the comparable dose rate from Payload A. Consequently, models for determining the dose rate at the top and bottom of the package were not required. Likewise, because the condition of the PAS-1 packaging under HAC is independent of the payload, a model of the packaging for accident conditions is also unnecessary.

The EM-70 Staff reviewed the above radiation model and agrees that it is reasonable and conservative.

### 5.3.4 Shielding analyses

SARP calculations of the dose rate at the side of the PAS-1 with Payload B were performed with MicroShield, which computed both the photon flux and dose rate. The results, presented in Section 5.2 and Appendix 5.3 of the SARP, indicate that the dose rate at the side of the package is approximately 0.047 mR/h. EM-70 Staff confirmatory calculations using MicroShield (Version 4.21) considered only the contribution of the  $^{137m}\text{Ba}$  and  $^{60}\text{Co}$  gamma source and were in agreement with those presented in the SARP. As noted above, the very small dose rate calculated for Payload B was based on very conservative assumptions.

The EM-70 Staff also examined the significance of the gammas resulting as bremsstrahlung radiation from the decay of  $^{90}\text{Y}$ . Supportive analysis provided by the applicant as part of the review process indicated that the contribution from bremsstrahlung is not significant. The EM-70 Staff performed confirmatory analysis using a bremsstrahlung spectrum calculated by ORIGEN2 for the beta decay of  $^{90}\text{Y}$  in both a water and  $\text{UO}_2$  medium. Dose rates from these spectra were calculated using the same MicroShield model as in the decay gamma calculations. Although the results of these calculations indicated a higher dose rate from bremsstrahlung than that reported by the applicant, the

EM-70 Staff concurs that the dose rate from Payload B is still significantly less than that of Payload A.

As presented in Section 5.1 of the SARP, the dose rate at the side of the PAS-1 with Payload A is approximately 106.7 mR/h, several orders of magnitude larger than that with Payload B. Consequently, the radiation levels from Payload B satisfy the Acceptance Criteria set forth in Section 5.2.

#### **5.4 Findings and Conclusions**

The shielding analyses for Payload B presented in the SARP and confirmed by the EM-70 Staff, demonstrate that the package design meets the applicable requirements for shielding in 10 CFR Part 71.

### **Chapter 6, CRITICALITY EVALUATION**

#### **6.1 Areas of Review**

Chapter 6 of the PAS-1 SARP was reviewed for adequacy of the criticality design and analysis for Payload B of the PAS-1 packaging. Payload A, addressed in the NRC review, did not contain fissile material.

#### **6.2 Acceptance Criteria**

A package is exempt from fissile material classification and from the fissile material standards of 10 CFR Part 71 Sections 55 through 61 if its contents include no more than 15 grams of fissile material.

#### **6.3 Review Procedures**

Section 1.2.3.2 of the SARP limits the fissile material in Payload B to no more than 15 grams of fissile material. Section 6.0 of the SARP calculates the maximum quantity of anticipated fissile material in Payload B, which is substantially less than 15 grams, and Section 7.6.1.5.4 provides for verification of the fissile contents in Payload B prior to shipment. The EM-70 Staff has reviewed the procedure for preparing Payload B and finds them to be adequate to ensure that the fissile content is less than 15 grams.

#### **6.4 Findings and Conclusions**

The applicant's criticality analysis, as confirmed by the EM-70 Staff, demonstrates that the PAS-1, Payload B packaging meets the criticality requirements of 10 CFR Part 71.

## **Chapter 7, Operating Procedures**

### **7.1 Areas of Review**

The PAS-1 SARP Chapter 7, Operating Procedures, was reviewed and approved by the NRC Staff for adequacy of the PAS-1 package with Payload A contents. Chapter 7 of the SARP was reviewed for the adequacy of the operating procedures as related to using the PAS-1 package for the shipment of Payload B.

### **7.2 Acceptance Criteria**

The operating procedures are acceptable if they ensure that Payload B satisfies the acceptance criteria set forth in chapters 1, 2, 3, 4, 5, and 6 of the SARP.

### **7.3 Review Procedure**

The SARP provides typical loading procedures for the Payload B configuration, and verifying samples from a tank to be shipped as Payload B.

The procedure presented in the SARP for verifying samples to be shipped as Payload B requires that prior to taking measurements for payload material categorization, applicable instrumentation shall be calibrated against standard materials of known concentration and the error bands determined. Duplicate analyses will be performed to assure that heterogeneity of the sample is not a significant contributor to the variance in the measurement of analyte concentration. During analyses of payload material, standards with known concentrations will also be analyzed. Additionally, matrix spikes will be added to fractions of the sample and analyzed to provide an indication that the sample matrix does not interfere with the measurement of concentration on that specific sample. Uncertainties of operations conducted in the analytical laboratory will be provided and added to the measurement data. The experimental uncertainties added to the measured data must be less than the bounding values for the material categories. If the bounding limits of any of the material categories are exceeded, that sample is disqualified from shipment using the PAS-1.

The operating procedures presented in the SARP for Payload B were reviewed by the EM-70 Staff and found to be in compliance with regulatory requirements except that hot spots of radioactivity in the sample might not be represented by the analyte. The 200 mRem/hr regulatory limit on the radiation rate at the surface of the package provides protection from hot spots that are not represented in the analyte for NCT. However there is no protection from hot spots not represented in the analyte exceeding the 1000 mRem/hr at 1 meter regulatory limit for HAC. Accordingly the Certificate of Compliance for Payload B requires that the radiation dose rate of each sample container outside the sample carrier shall not exceed 1000 mRem/hr at 1 meter to assure that the 1000 mRem/hr limit on the radiation rate from the package following HAC will not be exceeded.

## **7.4 Findings and Conclusions**

In a review of the Operating Procedures, Chapter 7 of the SARP, the EM-70 Staff confirmed that the Operating Procedures provided in the SARP combined with the limit on the sample container radiation rate imposed via the Certificate of Compliance ensure that Payload B meets the acceptance criteria specified in Chapter 1, 2, 3, 4, 5, and 6 of the SARP and therefore meet the regulatory requirements.

## **Chapter 8, Acceptance Tests and Maintenance Program**

### **8.1 Areas of Review**

The PAS-1 SARP Chapter 8 was reviewed and approved by the NRC for adequacy of the acceptance tests and maintenance program associated with the use of the PAS-1 packaging with Payload A. The approved acceptance tests and maintenance program must be augmented for use in shipping Payload B contents. The EM-70 Staff has determined that the challenges to the Acceptance Tests and Maintenance Program imposed by Payload B are the higher pressure due to gas generation and the possibility of hydrogen attack on the stainless steel walls of the PCV particularly in the heat affected zones of the welds.

### **8.2 Acceptance Criteria**

The EM-70 Staff determined that the following additional acceptance criteria shall be imposed on the two PAS-1 packages, serial numbers 2162-026 and 2162-027, authorized for service with Payload B.

1. Both the PCV and the SCV shall be tested at an internal pressure at least 50% higher than the MNOP with Payload B to verify its ability to maintain structural integrity.
2. The PCV shall be examined before service with Payload B and annually while in service to detect any deterioration.

### **8.3 Review Procedure**

The Acceptance Tests and Maintenance Program for the PAS-1 packaging with Payload A were reviewed and approved by the Nuclear Regulatory Commission. The EM-70 Staff determined that neither of the additional acceptance criteria for Payload B are addressed by the Acceptance Tests and Maintenance Program in Chapter 8. The Certificate of Compliance for shipping Payload B in the PAS-1 Packaging is conditioned upon the following:

1. Prior to first use for Payload B, the PCV and the SCV of a PAS-1 package shall be subjected to the 150% MNOP (150% MNOP = 50 psig) pressure test in accordance with 10 CFR 71.85(b). The following examinations shall be performed prior to and following the 150% test:

- (a) The inside and outside welds joining the end-plates to the cylindrical wall of the PCV shall be examined by liquid penetrant in accordance with Section III, Division 1, NB-5350. Any unacceptable indication (as defined by NB-5352) in the PCV, either before or after the pressure test, shall disqualify both PAS-1 packages, serial numbers 2162-026 and 2162-027, from shipping Payload B.
  - (b) The inside and outside welds joining the end-plates to the cylindrical wall of the PCV, the cylindrical wall, and the flat end-plates, shall be examined visually using straight edges, squares, and scales for dimensional distortion. Any distortion of the PCV wall, ends, or welds of a PAS-1 package, either before or after the pressure test, will disqualify both PAS-1 packages, serial numbers 2162-026 and 2162-027, from shipping Payload B.
  - (c) Following the 150% MNOP pressure test a leak test shall be conducted on both the PCV and the SCV in accordance with Section 8.3.2.2.1 of the SARP.
  - (d) The DOE Headquarters Certifying Official shall be provided the plan for the above tests and measurements 90 days before the tests and examinations, shall approve the test plans and the associated Quality Assurance plans, and shall be provided the opportunity to observe the tests and examinations.
  - (e) Records and photos of these examinations shall be retained for the lifetime of PAS-1 packages 2162-026 and 2162-027 plus 3 years in accordance with 10 CFR 71.91(c).
2. The PCV of PAS-1 package serial numbers 2162-026 and 2162-027 shall be inspected annually as follows:
- (a) The inside and outside welds joining the end-plates to the cylindrical wall of the PCV shall be examined by liquid penetrant in accordance with Section III, Division 1, NB-5350. Any unacceptable indication (as defined by NB-5352) in the PCV shall result in the immediate removal of the package from service and be reported to the DOE Headquarters Certifying Official.
  - (b) The inside and outside welds joining the end-plates to the cylindrical wall of the PCV, the cylindrical wall, and the flat end-plates shall be examined visually using straight edges, squares, and scales for dimensional distortion. Any dimensional distortion in the PCV shall result in the immediate removal of the package from service and be reported to the DOE Headquarters Certifying Official.

- (c) Records and photos of these examinations shall be retained for the lifetime of PAS-1 packages 2162-026 and 2162-027 plus 3 years in accordance with 10 CFR 71.91(c).
- 3. Upon removal of the sample carriers following each shipment of Payload B, the PCV shall be inspected for the presence of liquid or sludge. Liquid or sludge inside the PCV of a package, shall result in the immediate removal of the package from service and be reported to the DOE Headquarters Certifying Official.

#### **8.4 Findings and Conclusions**

The descriptions of the acceptance tests and the maintenance program in the SARP were reviewed. The EM-70 Staff determined that the acceptance tests and maintenance program given in the SARP are not sufficient for Payload B and that the Certificate of Compliance shall be conditioned as stated in Section 8.3 of this SER.

### **Chapter 9, Quality Assurance**

#### **9.1 Areas of Review**

The PAS-1 SARP Chapter 9 was reviewed by the NRC Staff for adequacy of the proposed and implemented quality assurance program for the PAS-1 packaging with Payload A contents. The NRC has approved the QA plan for the PAS-1 packaging with Payload A contents.

The approved QA plan for the PAS-1 packaging was augmented for use in shipping Payload B contents for the DOE. The SARP requires that the DOE and DOE contractors who maintain or repair the packaging, determine payload compliance, and use the package, develop a plan consistent with the QA program of the SARP in accordance with applicable DOE orders. The PAS-1 SARP portion of Chapter 9 that addresses a PAS-1 package with Payload B contents was reviewed for adequacy of the proposed quality assurance program for the package.

#### **9.2 Acceptance Criteria**

The acceptance requirements for the Quality Assurance program are established in 10 CFR Part 71, Subpart H. This Subpart consists of an eighteen-element quality assurance program that is similar to the Basic Requirements portion of ASME NQA-1 (1994 Edition) but has been specifically tailored for the transportation of radioactive materials.

#### **9.3 Review Procedure**

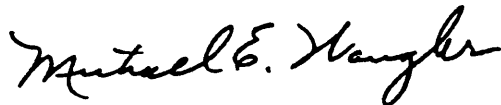
The Quality Assurance program at DOE sites specifies that DOE activities at sites which use, repair, or maintain the PAS-1 Packaging, including payload compliance, shall meet the requirements of several DOE Orders including DOE

Order 460.1A. Where applicable, these DOE Orders incorporate, by reference, 10 CFR Part 71, Subpart H.

The Quality Assurance verification and audits shall be performed to ensure compliance with the Operating Procedures (Chapter 7.0) and Acceptance Test and Maintenance Program (Chapter 8.0) of the SARP. Additional QA elements are identified to ensure that the Payload B loading activities are planned, performed, and verified such that Payload B does not exceed (1) the upper limits for fissile content and plutonium content and (2) the limits specified in Table 1.2.3-1 for Maximum Limits on Decay Heat, Percent Total Organic Carbon, Percent Aluminum, and Maximum Shipping Volume in the package. Other QA elements are identified to conservatively estimate (including uncertainties) anticipated radionuclide species and quantities as well as demonstrate that the payload meets the fissile exempt requirements of 10 CFR Part 71 Section 53.

#### 9.4 Findings and Conclusions

The descriptions of the quality assurance program were reviewed by the EM-70 Staff and found to meet the requirements of Section 9.2 (Acceptance Criteria) except that to satisfy 10 CFR 71.91(c) the record retention period for design related documents must be the lifetime of the package plus 3 years as it is for other QA documents rather than just the package lifetime.



Michael E. Wangler  
Headquarters Certifying Official  
Office of Site Operations, EM-70

Date JUN 11 1998